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Application of Systemic Structural Theory of Activity in Unearthing Employee Innovation in Mine Work

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Abstract

The purpose of this paper is to examine the extent to which the possible formation of wildfire activities in an actor's subconsciousness and which goes unnoticed in the conduct of drilling/bolting activity in deep mines is we understand. It also sought to understand how the dynamics of this subconscious wildfire activity influences the mediation process between miners, as subjects of activity, and the objective for the drilling/bolting activity. The systemic structural activity theoretical approachis used to understand the different ways of knowing the world of mine work, in terms ofthe generation of new knowledge, and also in ways of helping stakeholders understand how to incorporate results or lessons learned from the systemic tasks entailed in drilling/bolting activity. Using qualitative data from interviews and video observations of bolting/drilling operations in a deep mine, parametric and morphological analyses were conducted to unearth miners' innovation in the world of work. The paper concludes that the functional efficiency and effectiveness of drilling/bolting activities in deep mines could be enhanced by understanding the interrelationship betweenminers'internal and external activities. That is,understanding miners' practical-external activity and the corresponding external tools they might need to enhance their mental activities towards developing successful performance enhancing strategies for negotiating problematic task scenarios in rock drilling/bolting activity.

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*Keywords:*Mining work; Organizational activity; Ergonomics; Systemic structural activity; Employee innovation

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1. Introduction

Organization may emerge through conversation, but they do not emerge for the sake of conversation. They emerge and continue to exist in order to produce goods, services, or less clearly definable outcomes for clients or users ([1]). In this regard, many attempts have been made to identify the root causes of the problems associated with organizational learning and to show a way forward ([2]). The vagueness of the key concept "organization" seems to be a major hindrance to progress ([3]). As noted by [2], researchers have tried to cope with this problem in different ways. Some base their argument on mentalistic analogies of individual learning (see [4,5,6]). Others, although speaking about "organizational learning", focus on a more limited unit of analysis within an organization such as a management team or an organizational routine or concentrate only on a specific aspect of the organization, for instance its corporate culture. Some writers propose that other concepts, such as "knowledge system" ([7]), "community of practice" ([8, 9]) or "activity system" ([10,11]) should be used in analyzing organizational learning ([2]). On his part [12] proposed the concept of "emerging object of activities" based on the argument that since organizations (as subsets of society) offer employees just some of a number of possible 'images and symbols to live with and live by', it then follows that the continuing enactment of organizational life is a process that draws upon organizational as well as non-organizational components. In this paper, this concept by [12] is positioned to be in line with the thinking of [13] that an organizational activity is oriented by the transformation of a need into an objective (or motive), and as such actionsare fundamental components of activities and are subordinate to specific goals. This position is based on the premise that the goal of an action is a conscious mental representation of the outcome to be achieved (i.e. by a subject of an organizational activity) with its function being the orientation of the action. The implication being that, activities are realized as goal-oriented actions and as such, each organizational activity has a history of its own and a historical analysis of this development is thus often needed in order to understand the current developmental situation of the organizational activity. In this paper, the signification of the concept of "actors' emerging objects of activities" in understanding the complexity that is normally associated with mining activity, as well as its implication for the teaching of human resource management and in organization studies is discussed. An attempt is made to understand the possible formations of wildfire activities ([14]) in an actor's sub-consciousness in the process of carrying our either drilling and/or bolting activity in mines, but which event tends to go unnoticed. The issue of how managers in organizations can learn to understand the dynamics of the actor's sub-conscious wildfire activity and its pervasion in the mediation process between the subject of activity (actors) and the underlying objective for mining activity. The germ-cell of this paper are as follows: To what extent have we really sought to understand the possible formation of wildfire activities ([14]) in an actor's sub-consciousness and which goes unnoticed in the conduct of drilling/bolting activity in deep mines? In the act of drilling and/or bolting, how can we learn to understand the dynamics of this subconscious wildfire activity and its significance in the mediation process of the drilling/bolting activity?

2. Literature Review

The complexity of the human work process is highlighted by the characteristics of its substructure whose basic components have been delineated by [15] as follows: (i) motive-goal as a vector which demonstrates the directional and energetic aspects of the work activity, (ii) knowledge and skills which demonstrate the relevance past experience to the work process, (iii) abilities related to the tasks to be performed, and (iv) work actions which are organized into a structure, and together present the method of work. Action in this sense implies both cognitive and motor action. The presence of the concepts of knowledge and action in the structure of work process also implies the existence of mental tools ([15]). Therefore, in the process of developing new work practices in an organization, it is important to see the key actors in the practice development exercise as learners of their new activities ([16]). The implication here is that when employees are not actively involved throughout the planning and implementation processes of the work practice, it often results in a poorly designed work system and a lack of employee commitment ([17]). This is because in the task interpretation process, the worker has to be able to involve his personal prerequisites such as experience, skills and physical constitution, as well as his/her context as part of social systems inside and outside the organization ([18]). Additionally, the worker has to solve all the problems that are not taken care of or misinterpreted when management design tasks ([19]). This observation is indicative of [20]'s argument that in a 'community of practice' individual thought is essentially social and is developed in interaction with the practical activities of a community, through living and participating in its experiences over time.

According to [15], all tasks undertakings have some problem-solving aspects. It has been noted by [15] that the complexity of a task depends on the number of static and dynamic components of the task and specificity of their relationship. In general, the more complex the task, the more the mental efforts required for its performance ([15]). The following major criteria for the classification of task have been recommended by [15]; (i) indeterminacy of initial data, (ii) indeterminacy of tasks, (iii) existence of redundant and unnecessary data for task performance (iv) contradictions in task conditions, and complexity or difficulty of task (vi) time restrictions in task performance (vii) specifics of instructions, and their ability to describe adequate performance and restrictions, and (viii) adequacy of subject's past experience for task requirements. Therefore, in order to understand work scenarios in bolting/drilling activity, it is important to move beyond the prevailing institutionalized approaches and knowledge by penetrating the situated and localized nature of mining activities in particular contexts ([16]). Miners simultaneously engage in both external and internal activity when doing mining work ([16]). External means of activity include components of equipment and external tools with which a subject interacts during the process of work ([15]). External tools of activity refer to presentational controls displays, screens, instructions, diagrams, and other media for conveying information to an operator. Internal tools of activity are conceptual models, images of the external world, skills, and knowledge used by an operator during activity ([15]). These interactions must, of course be responsive to external conditions and constraints. Effective alignment of external and internal tools of activity allows for the transformation of the object of work into a required product or result with maximum psychological and physiological efficiency. Individuals in this frame are not construed as a reactive organism, but as subjects whose actions are guided by voluntary, established goals ([15]). In this regard, bolting/drilling activity is a work process that includes a number of different tasks whose basic characteristics are structure, complexity, difficulty, and degree of physical effort ([21]). These tasks could be either skill-based or problem-solving in their orientations, and as such require different levels of automaticity with which they are performed ([15]). Skill-based tasks, such as production operations, require standardized methods of performance without logical decisions about the sequence of possible actions, and are performed in a rapid automatic way with minimum concentration ([15]). The structure of a task is therefore, the spatiotemporal organization of its elements and the actions to be performed by an actor, and as such influences the strategies of task performance ([15]). Automatically performed actions are kinds of skills entailing an individual's ability to organize knowledge into a system and efficiently use it to perform a particular class of tasks or to solve a particular class of problems ([22).

The model shown in Figure 1 below describes how a person creates a goal, subjective mental model of the situation, which type of the exploratory actions and operations are utilized, what types of possible mental models are developed, and how a subject selects preferable mental models, among others. This means that the product of orienting self-regulation activity is not the transformation of the real situation, but formation of mental representation of situation that precedes execution ([23]). At any particular time, cognitive processes are integrated to achieve a specific purpose of activity self-regulation, and this integration serves as the basis for the formation of functional blocks or mechanisms of self-regulation ([23]). A number of function blocks in a self-regulation model are constant. However, the context of these blocks, as it is highlighted below by [23]), changes constantly.

- The first functional mechanism is a goal of task (block 2). Overall, the goal of the task performs integral functions. It integrates all the mechanisms of self-regulation into a holistic, self-regulative system of activity. There is no activity without a goal. When the goal is not clearly formulated externally, the subject can formulate it himself/herself. Even though a goal lacks clear definition, it still exists for a subject. During task performance, such a goal can be formulated more specifically.
- There exists a mechanism as subjectively relevant task condition (block 9). This mechanism is responsible for development of stable or dynamic mental models of task. At this stage, a subject creates a subjective representation of the task. This mental model of the task can vary even if the instructions do not change. The mental model includes imaginative and verbally logical sub-mechanisms or sub-blocks. A subject develops a mental model in both imaginative and verbally logical forms.

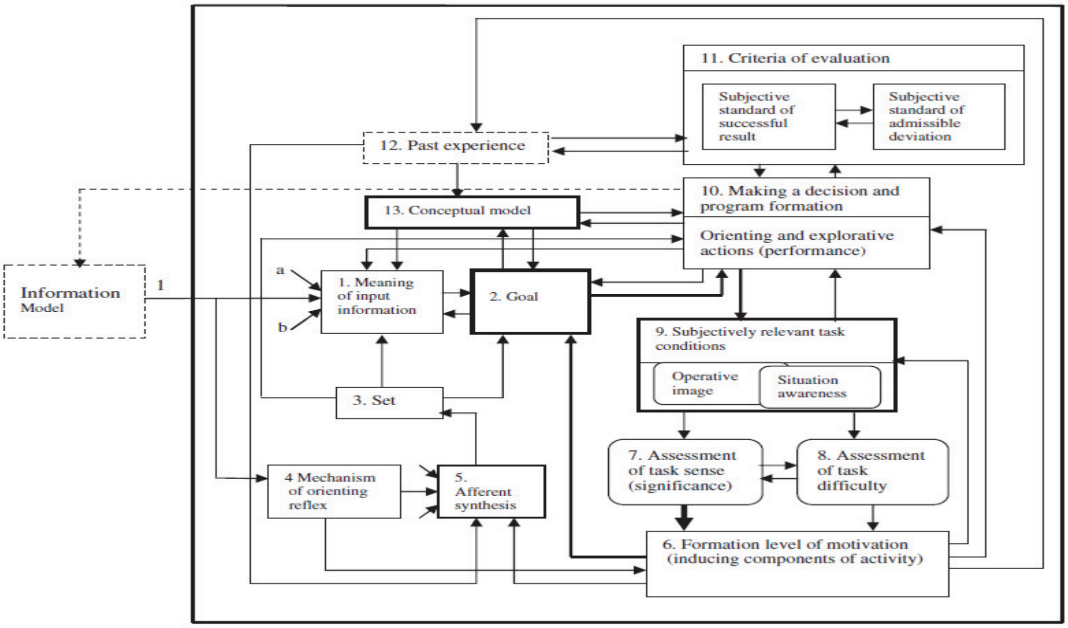

Fig. 2: Model of the self-regulation of orienting activity ([23]).

- The purpose of functional block number 8 listed above is assessment of task difficulty. This block is involved in the evaluation of objective complexity of the task. The task difficulty is a subjective characteristic of the task. The individual can underestimate or overestimate the objective complexity of the task and, as a result, select inappropriate strategies for goal attainment. Evaluation of task difficulty is a complex process that involves comparison of a subject's own abilities with demands of the task. The process may also involve taking inventory of other people's ability to compete this task. If an easier task is subjectively perceived as a more difficult one, the subject can reject the task or change requirements of the task.
- Functional block number 7 is responsible for emotionally evaluative aspects of activity where the subject evaluates personal significance of the goal or task itself. The block 'sense' or 'significance' is an important mechanism that influences interpretation of meaning and facilitates the creation of the mental model of situation. Features relevant to the task goal, the significance of situation and motivational state of the subject are selected for the interpretation of meaning out of the multitude of its semantic features.
- Motivational aspects of activity, functional block 6, depend on the mechanism of sense. First, the motivational block is an inducing mechanism of activity. Existence of blocks 6 and 7 in the self-regulation process makes it clear that not only cognitive but also emotionally motivational components affect activity regulation. It is important to note, according to the concept of self-regulation, that in SSAT, the goal is cognitive, and motivation is an energetic component of activity. Activity during task performance involves multiple motives. However, there is only one overall goal of task and a number of different sub-goals of separate underlying actions required to complete that task.
- Functional block 11 (criteria of evaluation) is involved in the evaluation of outcomes of activity. This block consists of two sub-blocks: 'subjective standard of successful result' and 'subjective standard of admissible deviation'.
- Block 'subjective standard of successful result' is responsible for development of a subjective standard of success. This standard can significantly deviate from objective requirements or goal of the task. Subjective standards of success are dynamic in nature and change during task performance. The block 'subjective standard of admissible deviation' performs specific functions such as determining what admissible deviations from required standards of success are possible.

It has been explained by [23] that during task analysis, consideration need not be given to all function blocks in the model. Focus should rather be on only those that play the most important role in the considered task performance. This therefore requires that attention is paid to not only separate function blocks, but also their interrelationships. The only block that can influence external situation in this model is block 10 ([23]). According to [23]), this happens only when a person uses external exploratory actions that change the situation.

3. Methodology

Qualitative data was collected through interviews with two (2) experienced miners as well as direct observation and video recording their drilling/bolting activities on two consecutive occasions for periods of four 4 hours. The interviews were transcribed and the motions captured in the video critically examined. Using the systemic analytical approach as the basic paradigm for the analysis of positioning actions ([23]) in the drilling/bolting activity in deep mines, both morphological and functional analyses were conducted. In the morphological analysis, the constructive features of the rock drilling activity, entailing the logical and spatio-temporal organization of the cognitive behavioral actions and operations involved, were described. In describing the structure of the rock drilling activity, the work process was subdivided into tasks. These tasks were analyzed individually in terms of mental and motor actions and operations. In the functional analysis, potential strategies of activity performance associated with the miners' actions and their corresponding operations, identified as constituting as functional blocks (see Figure 1) were analyzed qualitatively using systemic principles ([15]). This allowed for the evaluation of varieties of performance indicators, such as time and errors, and also the selection of the most efficient strategy. Functional analysis was conducted based on studying the miners' mechanism of activity self-regulation, which is critical for understanding the drilling/bolting activity as a system ([15]). The following functional blocks (see figure 1 above) were considered in analyzing the actions and operations undertaken by miners in the rock drilling activity:

- Block 2: Goal.
- Block 12: Past experience.
- Block 11: Criteria of evaluation block include two sub-blocks: 'subjective standard of successful result' and 'subjective standard of admissible deviation.
- Block 10: Making a decision and program formation: orienting and explorative actions (performance).
- Block 9: Subjectively relevant task conditions responsible for development of stable or dynamic mental models of task or situation.
- Block 8: Assessment of the task difficulty.
- Block 7: Assessment of the sense of task or task significance.
- Block 6: Formation of the level of motivation.

In the functional analysis, each of the functional block is viewed as a self-regulative system ([22,24]) in which the miners use their procedural knowledge in various ways. The units of analysis, viewed within the Vygotskian perspective ([15,25]), are the miners' cognitive and behavioral motor actions and operations. The cognitive and behavioral actions and operations in the object-oriented activity are analyzed from the perspective of the individual miner using technological tools in production work (drilling/bolting) to achieve results.

4. Results and Discussion

Observations and video recordings of the miners' engagement with the drilling/bolting activity show that a miner's individual object-oriented activity consists of both physical and mental actions and operations whose characteristics are influenced by past experiences. The functional appraisal of this activity shows that the object of a miner's self-regulation of orienting activity to be two folds. The object, in terms of the miner's physical activity, is the conduction of production (rock) drilling operations, based on informed decisions and programs to orient explorative actions towards performance enhancement, sense-making in task performance, and determination of motivational level. In terms of the miner's mental activity, the object is the simultaneous observation of the production drilling work, assessment of task difficulty, listening to communication models in order to enhance the development of stable or dynamic mental models of task or situation for enhancing the relevant task conditions. The object also includes the setting of subjective standard of "successful results" and also "admissible deviation". Morphological analysis of the miners' mental assessment of task difficulty showed that; they view the use of tractor technology with more than one robotic arm (i.e. boomer) for production drilling tasks as excessive for one operator to handle. The miners' related the perceived task overload to the difficulty an operator encounters in his/her ability to focus on the computerized programming command for the automated rock drilling actions and operations using the multi boomers. The miners viewed such situation as distracting them from developing the requisite dynamic mental models of task or situation which are required for enhancing the quality of the relevant task conditions. The miners view that even in situations where high technology robotic loaders that are remotely controlled from safe distances are used for important task components in production drilling activity, the guide cameras used to manipulate the robots' movements do not guide their operations as efficiently as the direct use of the operator's human eyes. As such the operators, based on acquired experiences, mostly find ways to guide the technology for optimum performance. A sense of this was provided qualitatively by the miners as follows:

> The technology does not always get it right. Most of the time, I use the experience I have acquired over the years to guide the technology for optimum performance. I have also developed enormous knowledge on manipulating the technology to make my work activity easier.

The above observation is highlighted by the following exchanges between researcher and a miner;

*Researcher:*So at times the work can be frustrating.

Miner: Oh yes.

*Researcher:*How do you feel now? The machine is not behaving well.

Miner: Yes, because it is fighting a hard rock which is difficult to penetrate.

*Researcher:*How do you know that the rock is difficult to penetrate.

Miner: From the noise being produced. The sound is different when the rock is not difficult to penetrate

Researcher: How did you know these differences?

Miner: I learnt it from experience. Look at the drilling of this here, bad! It took me almost six minutes.

*Researcher:*So, using the robots here does not solve all your problems ?

Miner: Yeah, at times.We need to use techniques we have developed from our experiences to help the machine work better.

*Researcher:*So at the end of the day, will you let someone know that you did this during the work

Miner:No.

Researcher: Why?

Miner: Because I don't think about it. Sometimes you want to go faster they will ask you to wait. You will wait and wait and …

Researcher: I know you want to go faster. Going faster means you are helping management to make more money.

Miner: Yeah! The more the machine works, the more money…..

Researcher: So, don't you think that there has to be a way for managers to appreciate what you have just done, that is, to know that when you are working and something happens, you repair it yourself.

Miner: Yes I understand. You have to do it.

*Researcher:*Maybe management also doesn't know that you do this kind of repair works here.

Miner: No! They know, but they don't care.

*Researcher:*So, how do you feel, when you get the sense that you are sacrificing, but they (i.e. management) don't care.

Miner: I feel bad! You know the song "bad to the bone"

Functional analysis of the scenario above shows that the miners possess procedural knowledge developed overtime on various objective activities, but which remained shared. This procedural knowledge is used by the operators to negotiate technology-based standardized task patterns in bids to overcome task repetitiveness and also to increase their productive capacities in terms of waste removal in production time. The miners also use their procedural knowledge to overcome subjective perceptions of technological shortcomings in their task undertakings (based the notion that technologies do not always get it right). In some instances, in the bolting operations, operators negotiate tasks to make them move faster. For example, it was found that operators of the high technology machine in the roof drilling and bolting operations in the deep mine used techniques enhanced by old mining culture to negotiate and accelerate the tasks. They use of their understanding of the sound produced in the machine-rock interaction to instinctively detect and negotiate round an impenetrable rock section. A sense of this is provided by the following extract of the direct conversation between researcher and miner;

Researcher: So like this, is it something you developed from your skills over the years?

Miner: Yeah. It is instinct.

Researcher: So it is instincts?

Miner: Yeah!

Researcher: But this instinct. Do you think it can be used in designing a better technology? That is your instinct. If something doesn't work, I have to do this ……..

Miner: Yeah, you can wake me in the middle of the night, and I can do it like this.

Researcher: If management comes to you today and say, "we now know that you have good ideas so write them down on a paper and give it to us, what will you tell them?

Miner: I will write it down and give it to them

Researcher: For free or you will ask them to pay you for your knowledge?

Miner: They should pay me for my knowledge.

Based on the analysis above, it is argued that since organizations possess technologies (i.e. techniques for processing raw materials and/or people) for accomplishing work, organizational activity then emphasizes a work system design in which technology affects social relations in organizations by structuring transactions between roles that are building blocks of an organization ([21]). In this respect, [21] argues that application of systemic-structural activity theory stands to provide an understanding of the various processes that is entailed in digitized human work which can be used to design a harmonious work environment integrating the human, technical and the social system, towards increased productivity in the deep mine industry. The findings from the morphological analysis showed that relationship between the miners' external behavior and internal psychological functions are mutually regulated ([21]). This shows a degree of commonality in the cognitive characteristics of the miners' internal mental activity and the regulative nature of their external behaviors towards the drilling/bolting activity undertakings. This finding is underscored by the argument supporting the mutual interdependence of mental development, semiotic mediation and external practical activity which do not exist separately ([15, 26]). The sense here is that an inter-subjective aspect of activity, manifested as innovative skills for task negotiation, is observable in a miner's individual activity.

Findings from the functional analysis support the miners' notion of time reduction in same task undertakings using procedural knowledge to determine penetrable and non-penetrable sounds differences to negotiate an action in an activity. It also portrayed the structure of the miners' activity during task performance as a logically organized system of cognitive and motor actions and operations ([27]) that enhances innovation ([21]).This shows that the specificity of the drilling/bolting activity is underlined by the interdependence of the miner's practical activities and symbolical activities, each of which is in constant transformation of the other ([21]). Since the practical actions in the drilling/bolting activity have clearly defined object, it then entails semiotic mediation ([15]). The occurrence of such mediation is highlighted by the conscious goal (including planning and understanding of the possible outcomes) with which the object-practical actions in the rock drilling activity are undertaken ([21]).Thus, for the miners engaged in drilling/bolting activity, their active exposure to diversity derived from years of practice and experience appeared to have increased the number of conceptual categories ([28]) they have developed for storing information ([21]). They also appeared to have procedurally developed new ways for integrating conceptual data in the actions and operations associated with drilling/bolting, and as a result provided more insightful knowledge of the complex problems and solutions in the drilling/bolting activity. The implication here is that the miners, being cognitively complex persons tend to be open in their beliefs and relativistic in their thinking, as well as have a dynamic conception of their work environment ([21]).

5. Conclusion

The discussion has shown that the object-practical activity of the rock drilling activity in the deep mines is determined by the genesis and content of the miners' mind. In this respect, therefore, we conclude that the functional efficiency and effectiveness of the production drilling activity in future automated and digitized deep mines could be increased by identifying performance enhancing strategies that are used by workers to facilitate the social collaboration between them and the technology they use in order to their productivities. Identification of such performance must require an understanding of the interrelationship of internal and external activity which stands to determine the miners' practical-external activity and the corresponding external tools that they need to enhance their mental activities towards developing successful performance enhancing strategies in the rock drilling activity. By implication, understanding derived from such performance enhancing strategies could be integrated in the design of efficient and effective work systems and/or technology.

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